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SURFACE STORAGE OF EXPLOSIVES

BY

D. HARRINGTON AND R. G. WARNCKE

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SURFACE STORAGE OF EXPLOSIVES[1]

By D. Harrington[2] and R. G. Warncke[3]

INTRODUCTION

Although for many years considerable attention has been given to devising safe and efficient methods of using explosives, with some success, relatively little has been done to provide satisfactory storage facilities for them. This was known long before the present war began, but it was emphasized during the past 30 months' inspections of explosive magazines by employees of the Bureau of Mines in administration of the Federal Explosives Act of December 26, 1941. These inspections have revealed woeful inadequacy as well as definite hazards and the urgent need for obtaining better storage facilities either by remodeling old magazines or constructing new ones that would afford suitable protection for the contents against theft, fire, deterioration, and detonation.

The purpose of this paper is to offer suggestions and to show by sketches and drawings some of the fundamental features of suitable magazines. Type of construction and available materials differ with different localities, but the information herein contained can be applied to most magazines, whether already constructed or the construction of which is planned. It is hoped that this information will be helpful and will aid persons who are trying to provide suitable storage for explosives and detonators. It is also hoped that States and cities will be made aware of the unbelievable laxity practiced in storing explosives in the United States and will take some remedial action.

STORAGE OF EXPLOSIVES

Explosives are definitely perishable and, even more important, are inherently hazardous, so that, regardless of the amount to be stored, certain precautions must be taken to achieve reasonable safety. Two important goals must be striven for - (1) protection of the explosives within the magazine and (2) protection of life and of adjoining property.

Explosives should be protected against heat, extreme changes in temperature, moisture, fire, lightning, bullets and projectiles, and theft. Thus, the storage magazine should be weatherproof, fire-resistant, bullet-resistant, well-ventilated, and securely locked.

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[1] The Bureau of Mines will welcome the reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7307."
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The condition of storage is closely related to the safe and efficient use of explosives. Improper storage of explosives, detonators, and fuse may result in misfires or incomplete detonation, with probable consequent fire as well as other troubles, thereby adding another to the already numerous inherent hazards in blasting.

A small leak in a magazine roof or wall may allow cartridges to become wet and to deteriorate to an extent that, when used, either a misfire or incomplete detonation may result. A dilapidated magazine or one with its floor close to damp or wet ground is likely to expose at least some types of explosives (these include most of the permissible explosives used in coal mining and many of the dynamites used in noncoal mining) to moisture, which then may misfire, incompletely detonate, or burn rather than detonate, thereby creating a hazardous condition, especially if they are used in underground workings.

Poor ventilation or lack of ventilation within a magazine can be the indirect cause of serious accidents through bringing about modifications in the structure or composition of explosives thay may cause them to misfire, detonate, or burn. When air does not circulate freely in a magazine, the atmosphere may become hot or humid, and continued exposure to such an atmosphere has much the same effect as dampness upon the characteristics of some explosives.

Some of the worst accidents from explosives are caused by handling misfires or undetonated explosives in the bottom of drill holes or broken material that has been blasted. The fumes or gases from a burning charge also are extremely poisonous and may cause fatal accidents underground. It is imperative that deterioration of explosives, detonators, and fuse be prevented, and that magazines should be dry, well-ventilated, and reasonably cool.

The explosives magazine should be built on an isolated site or should be protected by artificial or natural barriers to prevent injury to persons or property in case of accidental detonation of the contents. As local conditions may intervene, making absolute prevention impossible, certain precautions should be taken to prevent damage should an explosion occur. Some of these are discussed in the following text.

Location

Magazines should be situated far enough away from other buildings or vital structures so that, in case of an explosion within the magazine, the least possible damage may be done to buildings or persons in the surrounding area. Some States and cities have laws or regulations that specify this distance. Where such laws do not exist, it is recommended that, insofar as feasible, the magazine location comply with the American Table of Distances.

(Table 1.) This table specifies the distances from inhabited buildings, highways, and railroads at which magazines containing various quantities of explosives should be located.

The mandatory regulations as to the location of surface magazines under the Federal Explosives Act state (as of June 1, 1944):

> Section 24 (c) (4).***. All storage magazines must be properly constructed, safely located, and securely locked.***.
>
> Section 25 (b) (2). Location of box-type magazines. Box-type magazines, when located outside a building, shall be securely anchored. No magazine shall be placed in a building containing oil, grease, gasoline, waste paper, or other highly inflammable materials nor shall a magazine be placed less than 20 feet from a stove or furnace or open fire or flame, or less than 5 feet from other sources of external heat.

In the administration of the Federal Explosives Act, it is also recommended that surface magazines be detached from other buildings in conformity with the American Table of Distances (see table 1), and that they be not nearer than 200 feet to any power plant, hoist house, mill, dam, or other vital structure or to any mine shaft, tunnel, or slope opening at the surface. In other words, the magazine should be removed at least 200 feet from any mine structure or opening, and the explosives and detonator magazines should be at least 100 feet apart if not barricaded or 50 feet if barricaded, the definition of barricading being given in table 1.

The magazine site should be selected with the thought of safety and protection as well as economy of operation. The topography of the ground should be considered carefully to take full advantage of protection offered by hills, rock ledges, spoil banks, dense woods or forests, etc. A site on sandy soil is preferable to one on rocky ground, though rock ledges can afford considerable protection; although wooded regions are desirable, precautions must be taken against brush or other fires.

The site should have good drainage to prevent dampness or moisture from penetrating the magazine. Dugouts and tunnels in sides of hills offer good protection for the storage of explosives, but if they cannot be well-ventilated and well-drained, they are not recommended.

In brief, the magazine should be located so that in the event of an explosion there would not be serious damage to life and property. Also, it should be placed so as to prevent damage to or deterioration of explosives because of dampness or unduly high or low temperatures; and although the magazine should be so isolated by natural or other barriers as to minimize loss of life or property if its contents were to explode accidentally, on the other hand, it should not be so far away that its contents could be stolen by mischievous boys or persons whose motives might be much less innocent.

TABLE 1. - American table of distances 1919 revision

Blasting and electric blasting caps		Other explosives		Inhabited buildings barricaded* (feet)	Public railway barricaded* (feet)	Public Highway barricaded* (feet)
Number over-	Number not over-	Pounds over-	Pounds not over-			
1,000	5,000			15	10	5
5,000	10,000			30	20	10
10,000	20,000			60	35	18
20,000	25,000		50	73	45	23
25,000	30,000	50	100	120	70	35
50,000	100,000	100	200	180	110	55
100,000	150,000	200	300	260	155	75
150,000	200,000	300	400	320	190	95
200,000	250,000	400	500	360	215	110
250,000	300,000	500	600	400	240	120
300,000	350,000	600	700	430	260	130
350,000	400,000	700	800	460	275	140
400,000	450,000	800	900	490	295	150
450,000	500,000	900	1,000	510	305	155
500,000	750,000	1,000	1,500	530	320	160
750,000	1,000,000	1,500	2,000	600	360	180
1,000,000	1,500,000	2,000	3,000	650	390	195
1,500,000	2,000,000	3,000	4,000	710	425	210
2,000,000	2,500,000	4,000	5,000	750	450	225
2,500,000	3,000,000	5,000	6,000	780	470	235
3,000,000	3,500,000	6,000	7,000	805	485	245
3,500,000	4,000,000	7,000	8,000	830	500	250
4,000,000	4,500,000	8,000	9,000	850	510	255
4,500,000	5,000,000	9,000	10,000	870	520	260
5,000,000	7,500,000	10,000	15,000	890	535	265
7,500,000	10,000,000	15,000	20,000	975	585	290
10,000,000	12,500,000	20,000	25,000	1,055	635	315
12,500,000	15,000,000	25,000	30,000	1,130	680	340
15,000,000	17,500,000	30,000	35,000	1,205	725	360
17,500,000	20,000,000	35,000	40,000	1,275	765	380
		40,000	45,000	1,340	805	400
		45,000	50,000	1,400	840	420
		50,000	55,000	1,460	875	440
		55,000	60,000	1,515	910	455
		60,000	65,000	1,565	940	470
		65,000	70,000	1,610	970	485
		70,000	75,000	1,655	995	500
		75,000	80,000	1,695	1,020	510
		80,000	85,000	1,730	1,040	520
		85,000	90,000	1,760	1,060	530

*See footnote on following page.

TABLE 1. - American table of distances 1919 revision (Cont'd.)

Blasting and electric blasting caps		Other explosives		Inhabited buildings barricaded* (feet)	Public railway barricaded* (feet)	Public highway barricaded* (feet)
Number over-	Number not over-	Pounds over-	Pounds not over-			
		90,000	95,000	1,790	1,075	540
		95,000	100,000	1,815	1,090	545
		100,000	125,000	1,835	1,100	550
		125,000	150,000	1,900	1,140	570
		150,000	175,000	1,965	1,180	590
		175,000	200,000	2,030	1,220	610
		200,000	225,000	2,095	1,260	630
		225,000	250,000	2,155	1,295	650
		250,000	275,000	2,215	1,330	670
		275,000	300,000	2,275	1,365	690
		300,000	325,000	2,335	1,400	705
		325,000	350,000	2,390	1,435	720
		350,000	375,000	2,445	1,470	735
		375,000	400,000	2,500	1,500	750
		400,000	425,000	2,555	1,530	765
		425,000	450,000	2,605	1,560	780
		450,000	475,000	2,655	1,590	795
		475,000	500,000	2,705	1,620	810

*Barricaded, as here used, signifies that the magazine is effectually screened from other buildings, railroad, or highway, either by natural features of the ground or by artificial barricades. These barricades shall be of such height that any straight line drawn from the top of any wall of the magazine (if the magazine has a gable roof, the line should be drawn from a point midway on the roof) to any part of the building to be protected, shall pass through such intervening natural or artificial barricade. Also, any straight line drawn from the top of any wall (if the magazine has a gable roof, the line should be drawn from a point midway on the roof) to any point at least twelve (12) feet above the center of the railroad or highway to be protected, shall pass through such intervening natural or artificial barricade. Where such barriers do not exist, distances should be doubled.

An artificial barricade should consist of a constructed mound of earth or sand fill with a minimum width of three (3) feet at the top. One or more of the sides may be supported by a concrete, timber or masonry wall.

Barricades

The safe location and construction of magazines and the use of barricades to minimize destruction of life and property should the contents of the magazine be detonated are closely related. A barricade may be defined as a mound of earth or other barrier between an explosives magazine and its surroundings, which, in event of explosion of the magazine's contents, will deflect or possibly absorb the force of the explosion so as to protect surrounding structures or persons. Magazines should be protected by barricades, either natural or artificial, regardless of the distance from other buildings or structures being protected. The distances given in table 1 should be used in choosing explosives-magazine locations and should be doubl where the magazine is not screened or protected by natural or artificial barriers or barricades. The distance of 100 feet between explosives and detonator magazines can safely be reduced to 50 feet by the erection of an efficient barricade. Similarly, distances between magazines and adjacent vulnerable structures may be reduced proportionately by use of barricading. An efficient barricade will limit or control the forces of an accidental explosion of the magazine by diverting them mostly upward and ordinarily will prevent serious damage to surrounding life and property. It is not practica or even possible to locate some magazines at the required distance, but the danger from them can be greatly lessened by building efficient barricades.

In building a magazine, advantage should be taken of natural barriers, such as the side of a hill, the bottom of a cliff or rock ledge, a depressi or a hollow with steep sides, a heavily wooded region, spoil banks, or, unde some circumstances, the top of a hill. All these provide a screen or barri that can function effectively as a barricade.

In the absence of natural barriers, artificial barricades should be erected, some types of which can be constructed without undue cost or effor Choice of a type will be governed largely by the material that is readily available or the ease of procuring it. A simple barricade can be erected around a magazine by scraping or hauling dirt and piling it close to the magazine; a concrete or timbered wall can be erected at least 4 feet from the magazine, and the dirt may be piled against the wall, the width at the top of the pile or bank being not less than 3 feet. An excavation made in the side of a hill for the magazine and the excavated dirt built up in fron makes an efficient barrier. When the structures to be protected are on the same plane as the magazine, all sides should be barricaded essentially to o above the height of the magazine.

Foundations

Magazines should be so constructed as to prevent the stored explosives from absorbing dampness and to allow free circulation of air beneath the floor of the magazine if it is a surface structure. Foundations should preferably be of brick, stone, concrete, hollow-tile or concrete blocks filled with concrete, or combinations of these. The height of the foundation above the ground at any point should be at least 1 foot. Foundations for magazines for only temporary storage may be wood posts, but the space between the ground and the floor should be enclosed and the enclosure cove with galvanized or sheet iron. In fact, the space under the floor of buil ing-type magazines of any kind should be enclosed to prevent entrance of persons, animals, sparks, or firebrands. Screened vents should be left in the foundation walls for ventilation. (See fig. 1.)

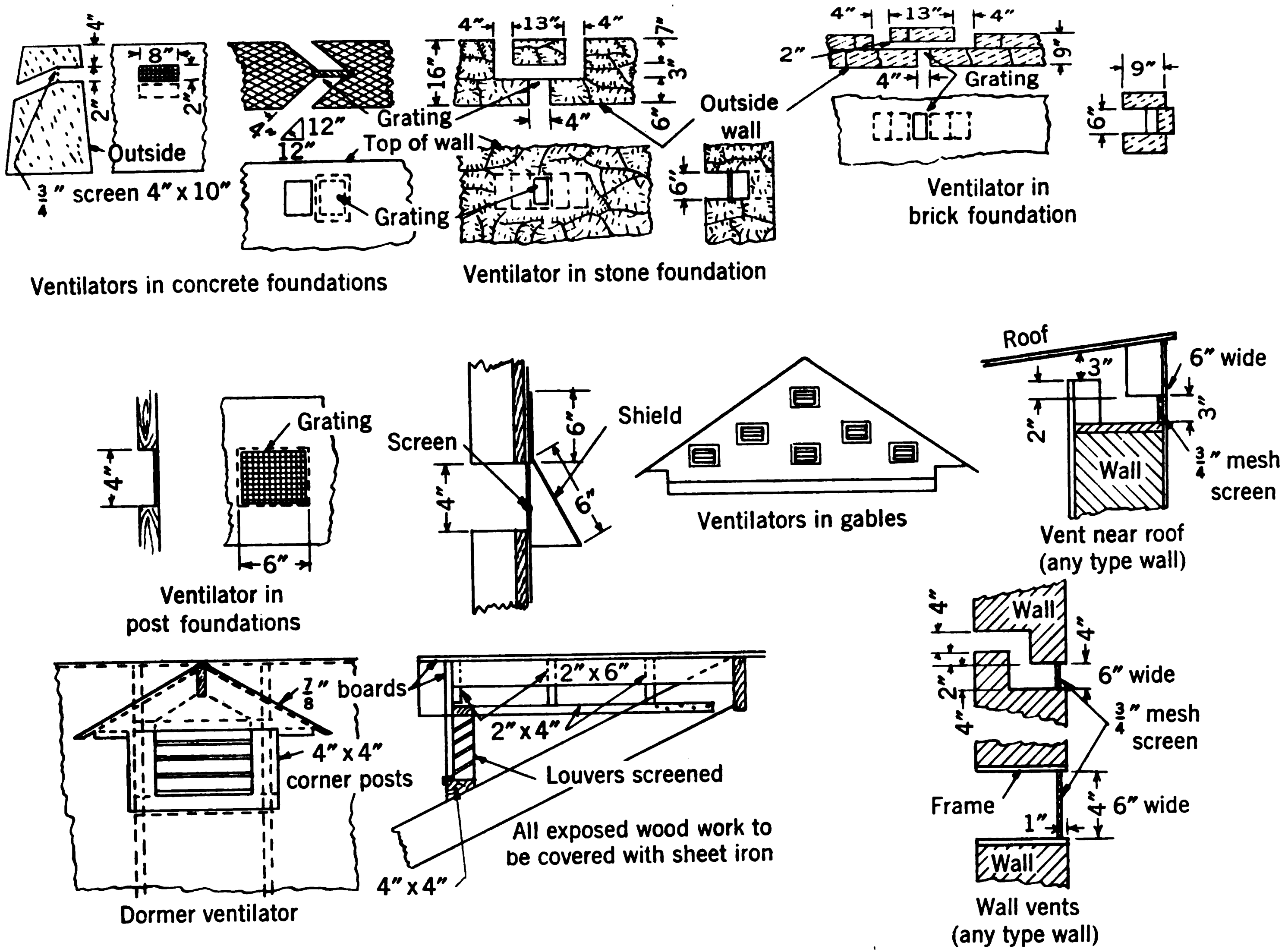


FIGURE 1.- Magazine ventilation.

Magazine Ventilation

To be properly stored, explosives should be kept in a dry magazine of uniform temperature; adequate ventilation is probably the best means of attaining such a condition. By means of vents in the foundation, walls, and roof, air can be made to circulate freely within the magazine. The mandatory requirements of the regulations of the Federal Explosives Act are:

> Magazines shall have no openings except for entrance and ventilation. Foundation vents shall be of an offset-type construction, and all vents shall be effectively protected with metal screening or otherwise constructed to prevent the entrance of persons, animals, sparks, or firebrands or the direct penetration of bullets that can detonate the explosives.

More consideration would be given to magazine ventilation if it were realized that two chief causes for the deterioration of explosives are moisture and excessive fluctuations in temperature; unless the air circulates freely in the magazine, the atmosphere may become excessively hot, cold, or humid. Long exposure to such atmospheric conditions has essentially the same effect upon some explosives as dampness, with the result that there may be misfires or incomplete detonation or burning of the explosives. With some types of explosives, unfavorable atmospheric conditions may cause the nitroglycerin to separate from the other ingredients; nitroglycerin "leaks," which makes the explosives more sensitive to shock or frictional impact, hence dangerous to handle.

Ventilators for various types of magazines are shown in some of the illustrations. Figure 1 shows methods of putting vents in foundations, walls, and roofs. The floor, except in front of the door, and the sand box or false ceiling should be set back at least 2 inches from the walls for ventilation. This is shown in several of the illustrations.

The following suggestions are offered with regard to ventilating magazines:

> Vents in foundations should be spaced not to exceed 6 feet, center to center, and should not be more than 6 inches in width and 12 inches in length.
>
> Roof ventilation may be through hip-roof and dormer vents, gable vents, or globe, star, or equivalent ventilators in the peak of the roof.
>
> Gratings for vents can be made by punching 1/2-inch holes in No. 12 flat galvanized iron or by use of strong screens.
>
> The size and number of ventilators will vary with climate, size of magazine, nature of stock, and probably other considerations.

A minimum number of vents would be one 12-inch globe or star vent for each 12 feet of magazine length, or two 4- by 6-inch openings in each gable for each 12 feet of magazine length, or 1 opening of approximately 1 square foot for each 15 feet of magazine length for hip or dormer vents.

None of the ventilation vents should be so large that a child could go through it.

Magazine Construction

The field representatives of the Bureau of Mines engaged in administer the Federal Explosives Act found magazines of various types and constructio Many of them were substantially built of concrete, stone, or hard-burnt bri more frequently, however, magazines have been built flimsily, as for instan a light framework of wood covered with corrugated iron, and little or no at tempt had been made to make them bullet-proof, theft-proof, fire-proof, or resistant to heat, cold, or moisture.

Stone, concrete, or hard-brick magazines generally are thought to be u desirable because of the possibility of flying missiles in case of an explo sion. The material used in the construction of a magazine should disintegrate and shatter easily if an explosion were to occur within the magazine, yet construction should be substantial enough to prevent theft.

The mandatory regulations of the Federal Explosives Act relating to construction of surface explosives storage-magazines follow:

Section 25. Storage of high explosives

(a) High explosives in amounts exceeding 125 pounds. All high explosives in amounts exceeding 125 pounds shall be stored in permanent magazines which are theft-resistant, fire-resistant, and bullet-resistant.

(1) Construction of permanent magazines. Permanent magazines shall be of a building type, an igloo or army type, a portable type, or a tunnel or dugout type, whether located on or exposed to the surface or underground. Walls of building-type magazines shall be substantially constructed of theft- and bullet-resistant materials. Walls shall meet the following standards or be constructed of other materials in a manner which will make them at least equally theft- and bullet-resistant:

(i) Solid construction, not less than 6 inches in thickness of materials such as concrete, masonry, medium soft brick, or wood; or

(ii) Filled construction, such as concrete blocks with the cells filled with screened sand, weak concrete, cement mortar, or other effective bullet-resistant filler; or exterior and interior wooden walls not less than 6 inches apart with the space between filled with screened sand, weak concrete, cement mortor, or other effective bullet-resistant filler, and the exterior walls covered with sheet iron not lighter than No. 26 gauge, or other fire-resistant material; or

(iii) Lined construction, such as steel plate not lighter than No. 14 gauge, lined with weak concrete, cement mortar, brick, or screened sand not less than 6 inches in thickness, or with hardwood not less than 2 inches in thickness, or with softwood not less than 3 inches in thickness.

The same standards shall govern the construction of any artificial enclosing wall for tunnel- or dugout-type magazines on or exposed to the surface of the ground. Any artificial enclosing wall for permanent underground magazines shall be substantially constructed of wood not less than 2 inches in thickness or of other material of equivalent or greater strength.

Foundations of building-type magazines shall be substantially constructed, and any space between the floor and the ground shall be enclosed in such a manner as to prevent the entrance of persons, animals, sparks, and firebrands.

Roofs of building-type magazines shall be fire-resistant and substantially constructed to resist theft, as for example, by 3/4-inch sheathing covered with sheet iron or slate. Roofs not constructed of fireproof material shall be covered with sheet iron not lighter than No. 26 gauge or other fire-resistant material. The roofs of magazines so located that it is possible to fire bullets directly through the roof into the explosives shall be made bullet-resistant by material of construction, or by a ceiling that forms a tray containing not less than a 4-inch thickness of sand or other equally effective bullet-resistant filler erected in the interior of the magazine, or by other methods.

Doors of magazines on or exposed to the surface of the ground shall be constructed of 3/8-inch steel plate lined with a 2-inch thickness of wood; or of a thinner steel plate with a greater thickness of wood, at the rate of 1 additional inch of wood for each 1/8-inch decrease in the thickness of the steel plate; or of wooden walls at least 4 inches apart and filled with screened sand or other effective bullet-resistant filler, the exterior being covered with sheet iron not lighter than No. 26 gauge, or other fire-resistant material; or of wood not less than 6 inches in thickness; or of reinforced concrete not less than 4 inches in thickness. Doors of magazines located underground shall be substantially constructed of wood not less than 2 inches in thickness or of other material of equivalent or greater strength.

Doors of all permanent magazines shall be equipped with two mortise locks; or with two padlocks fastened in separate hasps and staples; or with a combination of a mortise lock and a padlock; or with a mortise lock that requires two keys to open; or with a three-point lock. Padlocks and mortise locks shall be the equivalent of five-tumbler jarproof locks. Doors shall be provided with strong hinges, hasps, and staples attached by welds, rivets, or by bolts fitted with lock washers and nuts on the inside of the magazine and installed in such a manner that the fastening cannot be removed when the magazine is locked.

Magazines shall have no openings except for entrance and ventilation. Foundation vents shall be of an offset-type construction, and all vents shall be effectively protected with metal screening or otherwise constructed to prevent the entrance of persons, animals, sparks, or firebrands or the direct penetration of bullets that can detonate the explosives.

(2) Marking of premises. The premises on which a permanent magazine is located shall be conspicuously marked by signs containing the words "Explosives - Keep Off." Such signs shall adequately warn any person approaching the magazine of the presence of explosives, but the signs shall not be so placed as to direct general public attention to the location of the magazine. No signs shall be placed on surface magazines or barricades or be so located that a bullet passing directly through the face of a sign will strike the magazine.

(b) High explosives in amounts not exceeding 125 pounds. High explosives in amounts of 125 pounds or less may be stored in permanent magazines complying with the standards set forth in section 25 (a), including subsections (1) and (2). If not so stored, such high explosives shall be stored in box-type magazines which are theft-resistant.

(1) Construction of box-type magazines. Box-type magazines shall be strongly constructed of 2-inch hardwood or of 3-inch softwood or other equally theft-resistant material. Any metal magazine shall be lined with a nonsparking material. Doors or lids shall be provided with strong hinges, hasps, and staples attached by welds, rivets, or bolts fitted with lock washers and nuts on the interior of the magazine and installed in such a manner that the fastening cannot be removed when the magazine is locked. Box type magazines shall be equipped with at least one lock equivalent to a five-tumbler jarproof lock.

* * *

(3) Marking of magazines. Box-type magazines shall be painted red or another distinctive color and clearly and conspicuously marked "Explosives".

Section 26. Storage of low explosives

(a) Low explosives in amounts exceeding 125 pounds. All low explosives in amounts exceeding 125 pounds shall be stored in permanent magazines complying with all of the standards set forth in section 25 (a), including subsections (1) and (2), except that permanent magazines for the storage of low explosives need not be bullet-resistant. Any metal magazine shall be lined with a nonsparking material.

(b) Low explosives in amounts not exceeding 125 pounds. All low explosives in amount of 125 pounds or less may be stored in permanent magazines complying with the standards set forth in section 25 (a) or section 26 (a). If not so stored, such low explosives shall be stored in box-type magazines complying with all of the standards set forth in section 25 (b), including subsections (1), (2), and (3).

Section 27. Storage of detonators

(a) Detonators in numbers of 1,000,000 or more. All detonators in numbers of 1,000,000 or more shall be stored in permanent magazines complying with all of the standards set forth in section 25 (a), including subsections (1) and (2).

(b) Detonators in numbers of more than 5,000 and less than 1,000,000. All detonators in numbers of more than 5,000 but less than 1,000,000 shall be stored in permanent magazines complying with all of the standards set forth in section 25 (a), including subsections (1) and (2), except that permanent magazines for the storage of detonators need not be bullet-resistant. Any metal magazine shall be lined with a nonsparking material.

(c) Detonators in numbers of 5,000 or less. All detonators in numbers of 5,000 or less may be stored in permanent magazines as above indicated. If not so stored, such detonators shall be stored in box-type magazines complying with all of the standards set forth in section 25 (b), including subsections (1), (2), and (3).

(d) Storage with other explosives. No detonator shall be stored in any magazine containing high or low explosives or blasting-device heaters.

In addition to the above mandatory provisions of the regulations of the Federal Explosives Act with regard to surface storage of explosives, those in charge of the administration of the Act offer the following recommendations:

Recommendations As To Surface Magazines

1. Be well ventilated.

2. Have natural light or be lighted by portable electric storage lamps or by protected electrical systems, or by flood lighting from the outside of the magazine.

3. Have floors made of wood or other nonsparking material and have no metal exposed.

4. Be grounded if constructed of steel or covered with sheet iron.

Additional precautions against theft

Explosives must be protected against theft by storing them in magazines constructed and locked as required by the regulations.

Additional protection may be secured in appropriate cases by using

Recommendations

1. Mortise locks wherever practicable. When padlocks are used they should be protected by steel hoods or shields placed around the locks to prevent tampering. The hood or shield may be made from pipe or of steel large enough in diameter to enclose and protect the lock and hasp and at least 4 inches in length, securely fastened to the door by welding or by lugs that are riveted or bolted or fastened by some other secure method.

2. Fences.

3. Floodlights.

4. Gas bombs.

5. Alarm systems, such as the "electric eye", etc.

6. Additional guards or inspection by watchmen.

Precautions against fires

Precautions taken to prevent fires should include

Recommendations

1. Keeping the magazine clean.

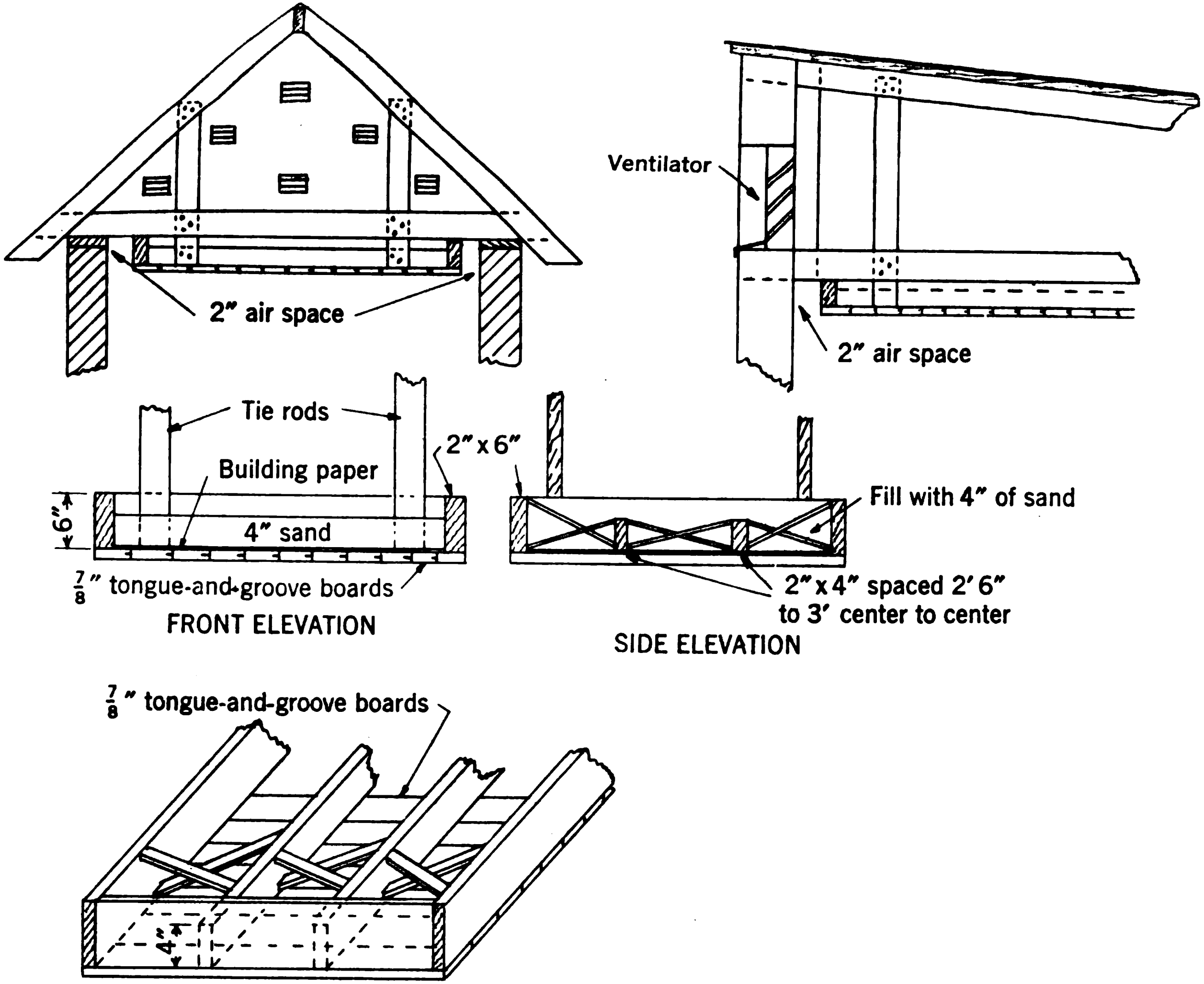
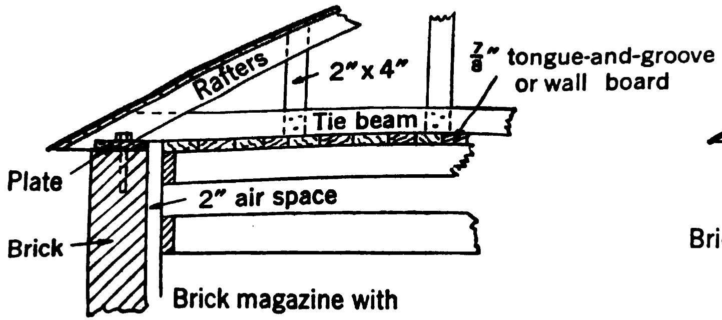
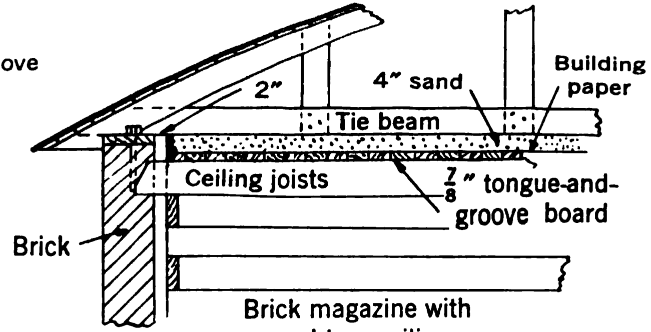


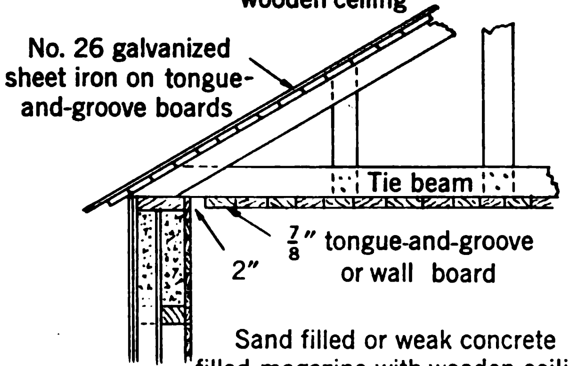
FIGURE 2.- A method of constructing a sand-tray ceiling. Side and end of box constructed of 2- by 4-inch boards, installed as needed, depending on size of box. Bottom of box is of 7/8-inch tongue-and-groove boards covered with building paper. Box to be filled to the top of the 2 by 4's with dry, coarse sand. Brace roof as needed to carry weight of sand tray. Tie rods may be of steel or wood, the number used depending on size of box.



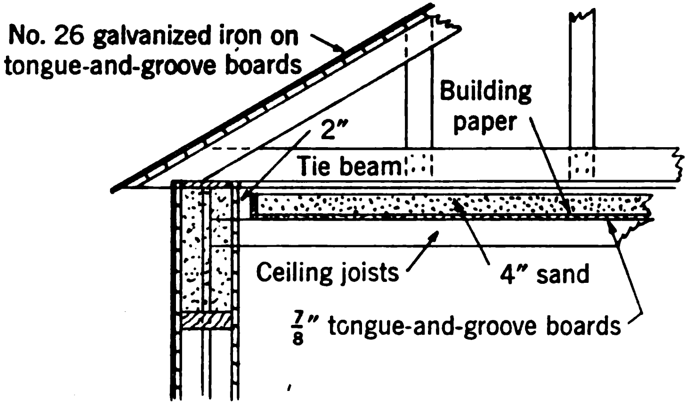
Brick magazine with wooden ceiling



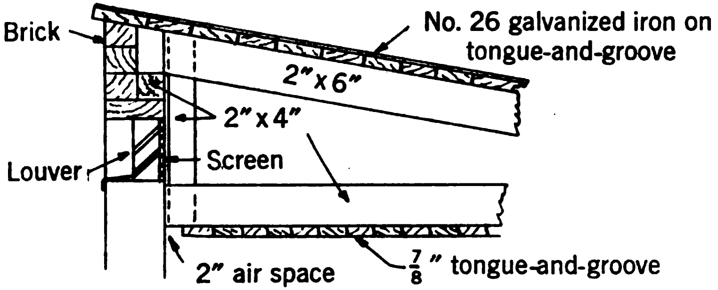
Brick magazine with sand-tray ceiling


No. 26 galvanized sheet iron on tongue-and-groove boards
Tie beam
7/8" tongue-and-groove or wall board
2"

Sand filled or weak concrete filled magazine with wooden ceiling


No. 26 galvanized iron on tongue-and-groove boards
Building paper
2"
Tie beam
Ceiling joists
4" sand
7/8" tongue-and-groove boards

Sand-filled or weak concrete-filled magazine with sand-tray ceiling



Sloping roof, any magazine

FIGURE 3.- Method of installing sand trays and ceilings in magazines of various types.

2. Keeping waste paper, sawdust, used empty boxes and containers, and other combustible material from accumulating in or around any magazine.

3. Keeping the surrounding area for 25 feet, and preferably 50 feet, in all directions free of rubbish, dry grass, or other material of a combustible nature and where feasible by covering the area with a material to prevent the growth of grass, weeds, and brush.

4. Prohibiting smoking, open lights, or other flame, or carrying of matches and smokers' articles into or around any magazine.

5. Storing black powder and high explosives in separate magazines.

Distributing magazines

Magazines used for distributing explosives and detonators must be constructed to meet the minimum standards of the regulations. The supply kept in such magazines should be limited to approximately 1 day's requirements. All recommendations applicable to storage magazines should be observed in the operation of distributing magazines.

The following drawings show various types of magazines that may be constructed of any of the above materials. Availability of materials will govern the type and construction of the magazine. These drawings are of approved-type magazines and should be followed in designing a new magazine. Magazines now in use usually can be changed with relatively little expense to make them conform to approved practice.

The roof of the magazine can be constructed of weak concrete, brick, or wood-frame and sheathing covered with sheet or corrugated iron or other fire-resistant material. Roofs of magazines situated so that it is possible to shoot directly through the roof into the explosives should be made bullet-resistant. This can be accomplished easily by constructing sand trays within the magazine. (See figs. 2 and 3.) Even though it is not necessary to make the roof bullet-resistant, it is good practice to put a ceiling in the magazine, as it contributes greatly to keeping the temperature stable.

The floor of the magazine should be of wood, and an opening should be left at least 2 inches from the wall for ventilation. It is bad practice to build magazines with dirt, concrete, or brick floors and foundations without ventilation openings. A wooden floor should be built over such floors, or the explosives in such a magazine should rest on benches or lattices of wood. All sections of the magazine should be ventilated.

Some means should be provided for grounding magazines constructed of steel and those covered with sheet iron. The entire roof and sides of the magazine shown in figures 4 and 12 are covered with sheet iron, and the iron portions are grounded with 1/2-inch iron rods extending from the four lower corners of the building, the ends of the rods being buried below the moistu line and attached to an effectively laid earth plate.

Magazines should have no openings except for entrance and ventilation.

Bureau of Mines Magazine[4]

As a result of experiments and of information furnished by the manufacturers of explosives, a cement-mortar magazine (figs. 4 and 12) was erect by the Bureau of Mines. Outside dimensions of the structure are 10 by 16 feet, and its capacity is 20,000 to 30,000 pounds of explosives.

The salient features of the magazine are the cement-mortar walls, slidi door and roof. The cement mortar is 6 inches thick in all walls and 3 inche thick in the roof and the floor. The door is secured by two substantial locks. No metal of any kind is exposed on the inside of the magazine. The ventilators above the floor are arranged to prevent the entrance of bullets and firebrands.

The means provided for ventilation have been found to be adequate, and, accordingly, the storage conditions are favorable for keeping the explosives from deteriorating. The cement mortar employed effectively resists penetration by rifle bullets and, because of its friable nature, offers the addi tional advantage that it will not be projected over the surrounding country in case of an explosion in or near the magazine. The galvanized-iron coveri is fire-resisting; it also serves as an excellent medium for protection agai lightning, as the four corners of the building are effectively grounded wit metal rods.

The concrete of the foundation consists of one part cement, three parts sand, and five parts gravel. The cement-mortar in the walls, door, and roo consists of one part cement to six parts coarse sand.

MISCELLANEOUS

The following rules, although not directly applicable to magazine construction, do apply to the safe operation of explosives and detonator magazines.

No detonators, tools, or other materials should be stored in a magazin containing explosives.

No high or low explosives or blasting-device heaters should be stored a detonator magazine.

No black powder should be stored with other explosives.

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[4] Hall, Clarence, and Howell, S. P., Magazines and Thaw Houses for Explosives: Bureau of Mines Tech. Paper 18, 1912, 34 pp.

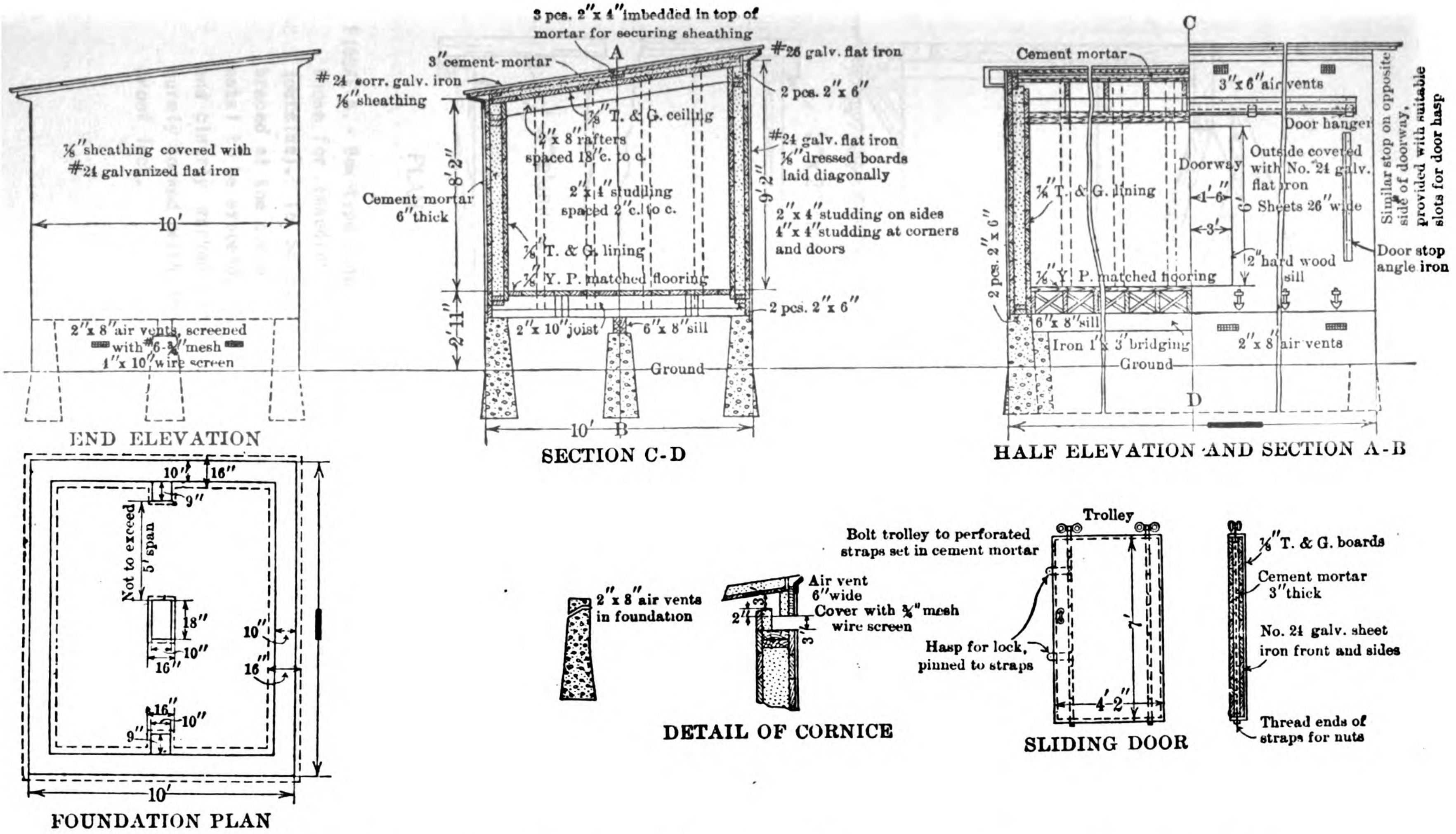

⅞" sheathing covered with #24 galvanized flat iron
10'
2" x 8" air vents, screened with #6-¾" mesh 1" x 10" wire screen
END ELEVATION
3 pcs. 2" x 4" imbedded in top of mortar for securing sheathing
A
3" cement-mortar
#24 corr. galv. iron
⅞" sheathing
#26 galv. flat iron
2 pcs. 2" x 6"
⅞" T. & G. ceiling
2" x 8" rafters spaced 18" c. to c.
2" x 4" studding spaced 2' c. to c.
#24 galv. flat iron
⅞" dressed boards laid diagonally
Cement mortar 6" thick
8'-2"
9'-2"
2" x 4" studding on sides
4" x 4" studding at corners and doors
⅞" T. & G. lining
⅞" Y. P. matched flooring
2 pcs. 2" x 6"
2'-11"
2" x 10" joist
6" x 8" sill
Ground
10'
B
SECTION C-D
C
Cement mortar
3" x 6" air vents
Door hanger
Doorway
Outside covered with No. 24 galv. flat iron
Sheets 26" wide
1'-6"
6'
3'
⅞" T. & G. lining
2 pcs. 2" x 6"
⅞" Y. P. matched flooring
2" hard wood sill
Similar stop on opposite side of doorway, provided with suitable slots for door hasp
Door stop angle iron
6" x 8" sill
Iron 1" x 3" bridging
2" x 8" air vents
Ground
D
HALF ELEVATION AND SECTION A-B
10"
16"
9"
Not to exceed 5' span
18"
10"
16"
10"
16"
16"
10"
9"
10'
FOUNDATION PLAN
2" x 8" air vents in foundation
Air vent 6" wide
Cover with ¾" mesh wire screen
3"
2"
3"
DETAIL OF CORNICE
Bolt trolley to perforated straps set in cement mortar
Trolley
Hasp for lock, pinned to straps
7'
4'-2"
SLIDING DOOR
⅞" T. & G. boards
Cement mortar 3" thick
No. 24 galv. sheet iron front and sides
Thread ends of straps for nuts

FIGURE 4.- Plan and sections of Bureau of Mines cement-mortar magazine.

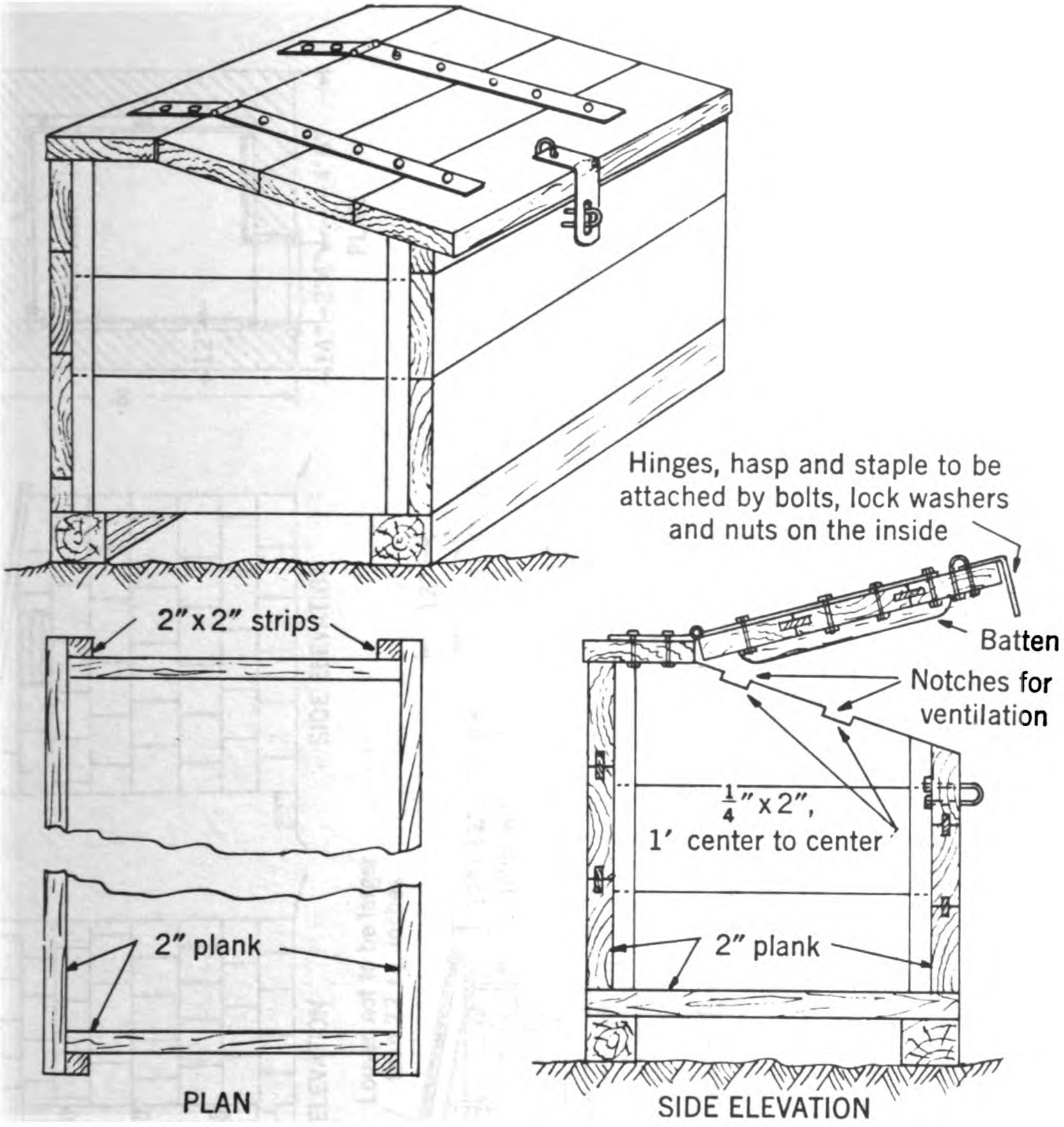

Hinges, hasp and staple to be attached by bolts, lock washers and nuts on the inside
2"x2" strips
Batten
Notches for ventilation
$\frac{1}{4}$"x2", 1' center to center
2" plank
2" plank
PLAN
SIDE ELEVATION

FIGURE 5.- Box-type magazine for storing small quantities of explosives or those for immediate distribution. Limited to storage of 125 pounds (outside). To be built of 2-inch hardwood or 3-inch soft wood, well-braced at the corners. Lumber to be smooth on the inside of box. No metal to be exposed. To be painted red or some other distinctive color and clearly marked with the word EXPLOSIVES. Lid or door to be securely locked with at least one lock equivalent to a 5-tumbler, jar-proof lock.

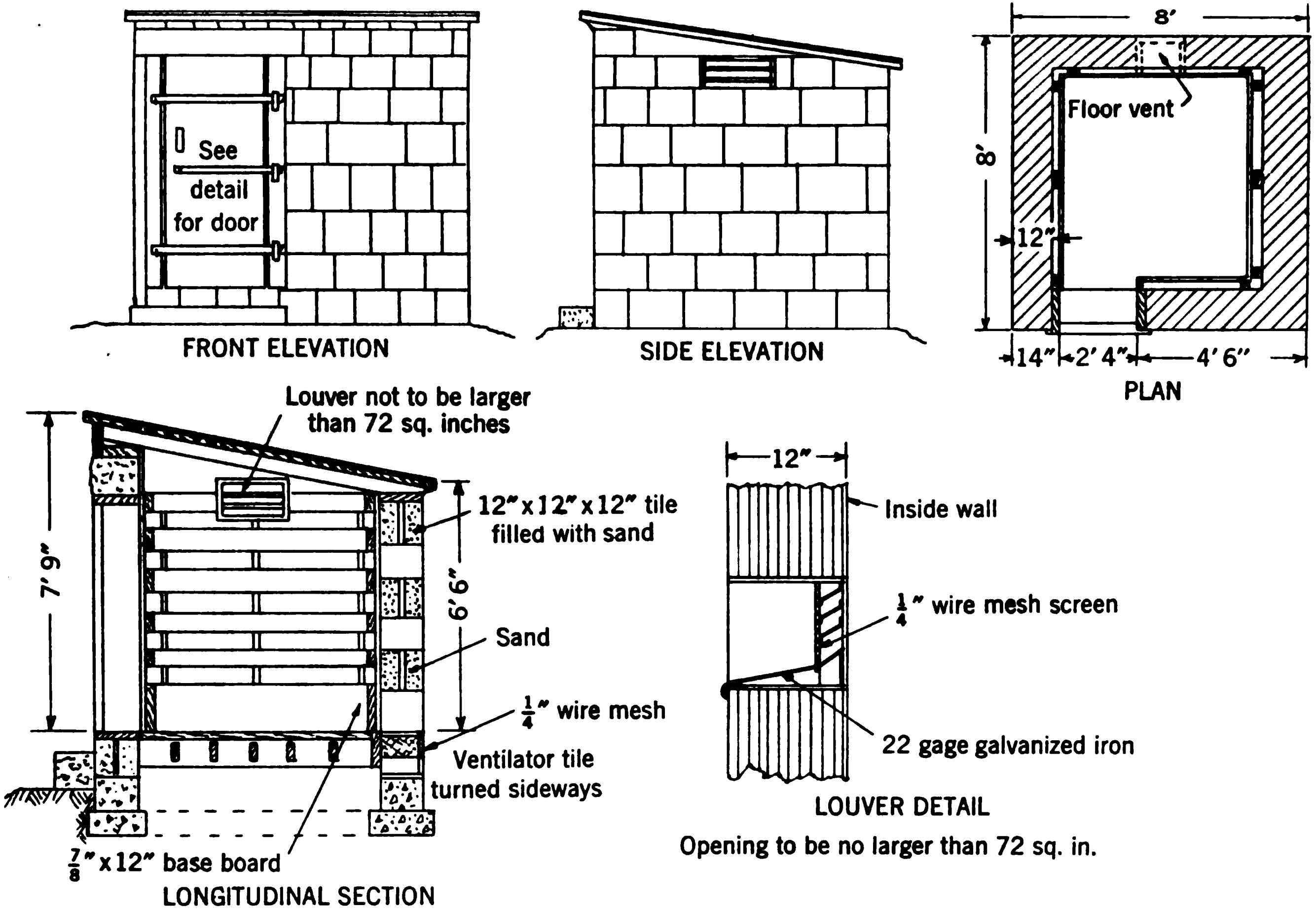
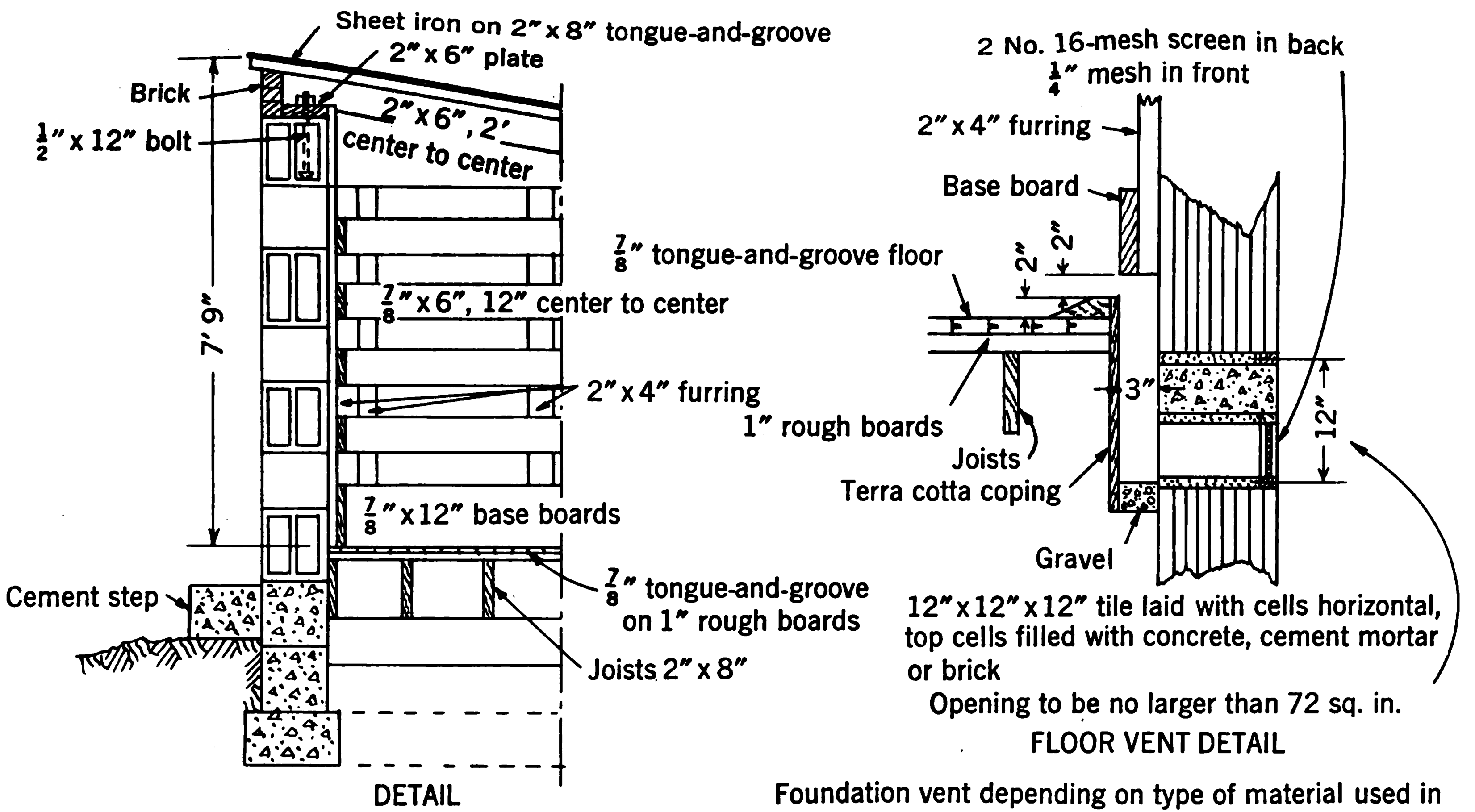
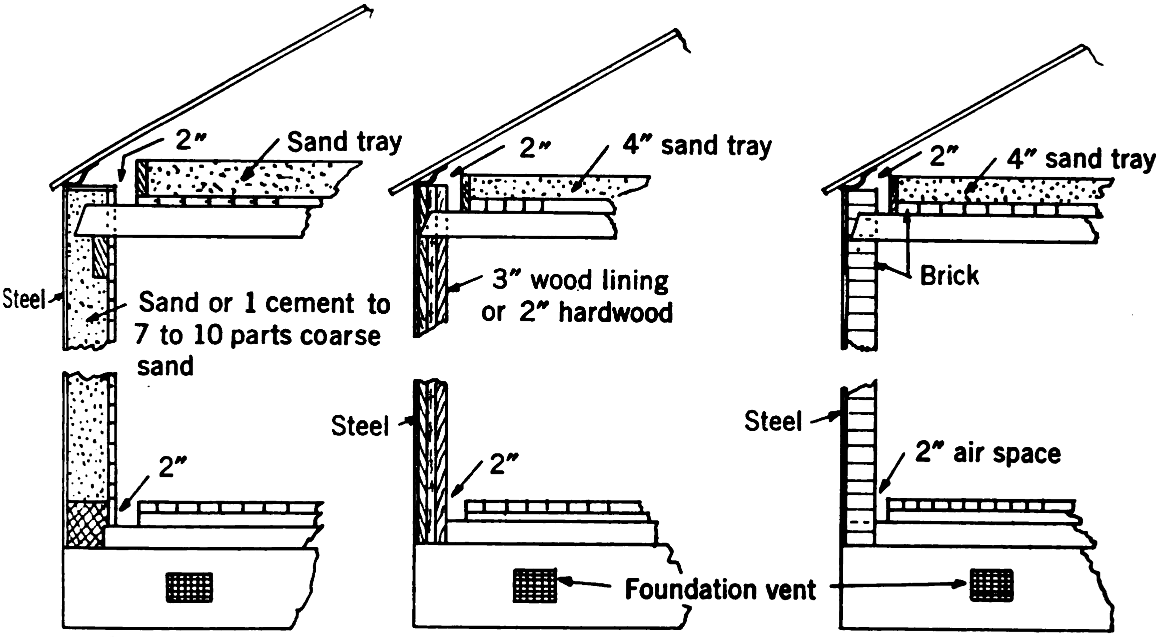


FIGURE 6.- Magazine of simple construction for storing small quantities of explosives (capacity about 4,000 to 4,500 pounds). Construction, 12- by 12- by 12-inch hollow tile with cells filled with screened sand. May be constructed of other material, such as soft brick, weak concrete or masonry, cement, or concrete blocks with cells filled with screened sand, cement mortar, or other bullet-resistant filler. Walls to be not less than 6 inches in thickness. Louvers or ventilators to be not larger than 72 square inches. Size and type of vents will depend on kind of material used. (See fig. 1.) Plan of foundation will vary with thickness of wall (sketch is for 12-inch walls).


Sheet iron on 2" x 8" tongue-and-groove
2" x 6" plate
Brick
½" x 12" bolt
2" x 6", 2' center to center
7' 9"
7/8" x 6", 12" center to center
2" x 4" furring
7/8" x 12" base boards
Cement step
7/8" tongue-and-groove on 1" rough boards
Joists 2" x 8"
DETAIL
2 No. 16-mesh screen in back
¼" mesh in front
2" x 4" furring
Base board
2"
2"
7/8" tongue-and-groove floor
1" rough boards
Joists
Terra cotta coping
3"
12"
Gravel
12" x 12" x 12" tile laid with cells horizontal, top cells filled with concrete, cement mortar or brick
Opening to be no larger than 72 sq. in.
FLOOR VENT DETAIL

Foundation vent depending on type of material used in construction; offset-type vent should be used. (See figure 1)

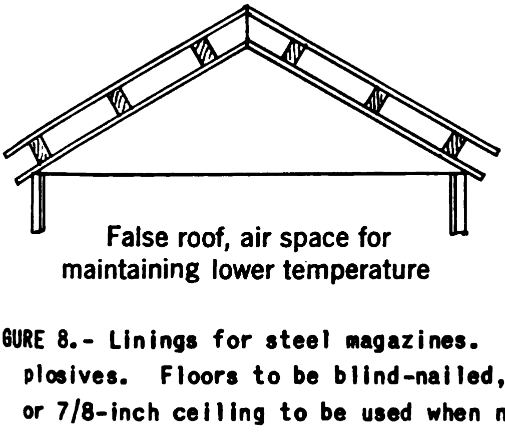
FIGURE 7.- Tile magazine.



Sand or weak concrete lining

3" wood lining

Brick lining



False roof, air space for maintaining lower temperature

FIGURE 8.- Linings for steel magazines. Metal should not come in contact with stored explosives. Floors to be blind-nailed, and lining nails to be countersunk. False roof or 7/8-inch ceiling to be used when necessary to maintain temperature in magazine.

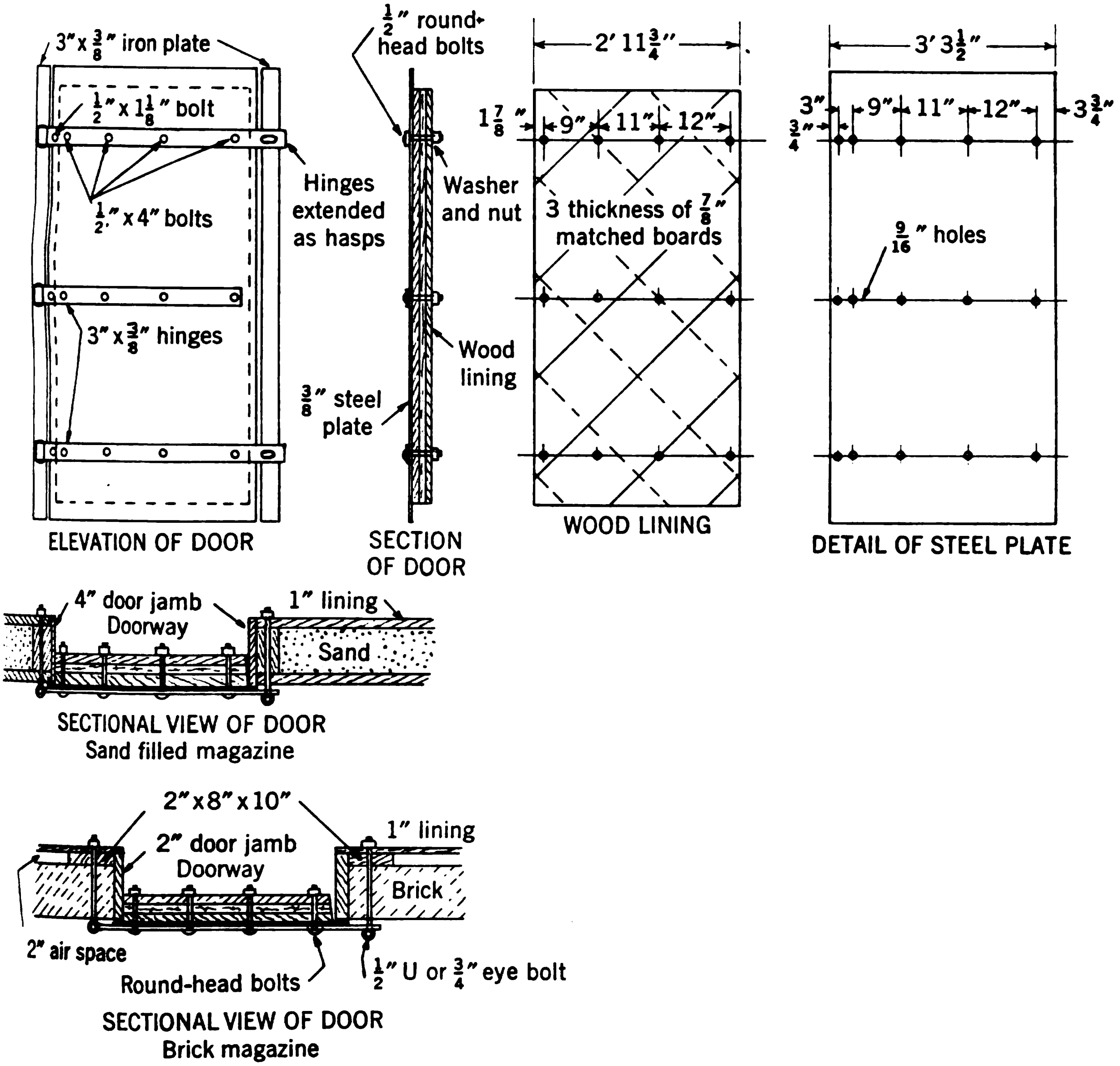


FIGURE 9.- Sketch of an easily constructed magazine door (can be used for a door of any dimensions). Three thicknesses of 7/8-inch tongue-and-groove boards are laid diagonally back of a 3/8-inch steel plate. Doors should be constructed of 3/8-inch steel plate and lined with at least a 2-inch thickness of wood. A thinner plate may be used when an additional inch of wood is used for each 1/8-inch decrease in thickness of steel plate. Hinges and staples to be attached by welds, rivets, or bolts fitted with lock washers and nuts on the inside. Door to be equipped with two padlocks fastened in separate staples. Top and bottom hinge strap to be extended to cover iron plate for hasp and either U or I bolt, as desired, for staple; or two hasps and staples could be attached if it is not desirable to use hinge strap as a hasp.

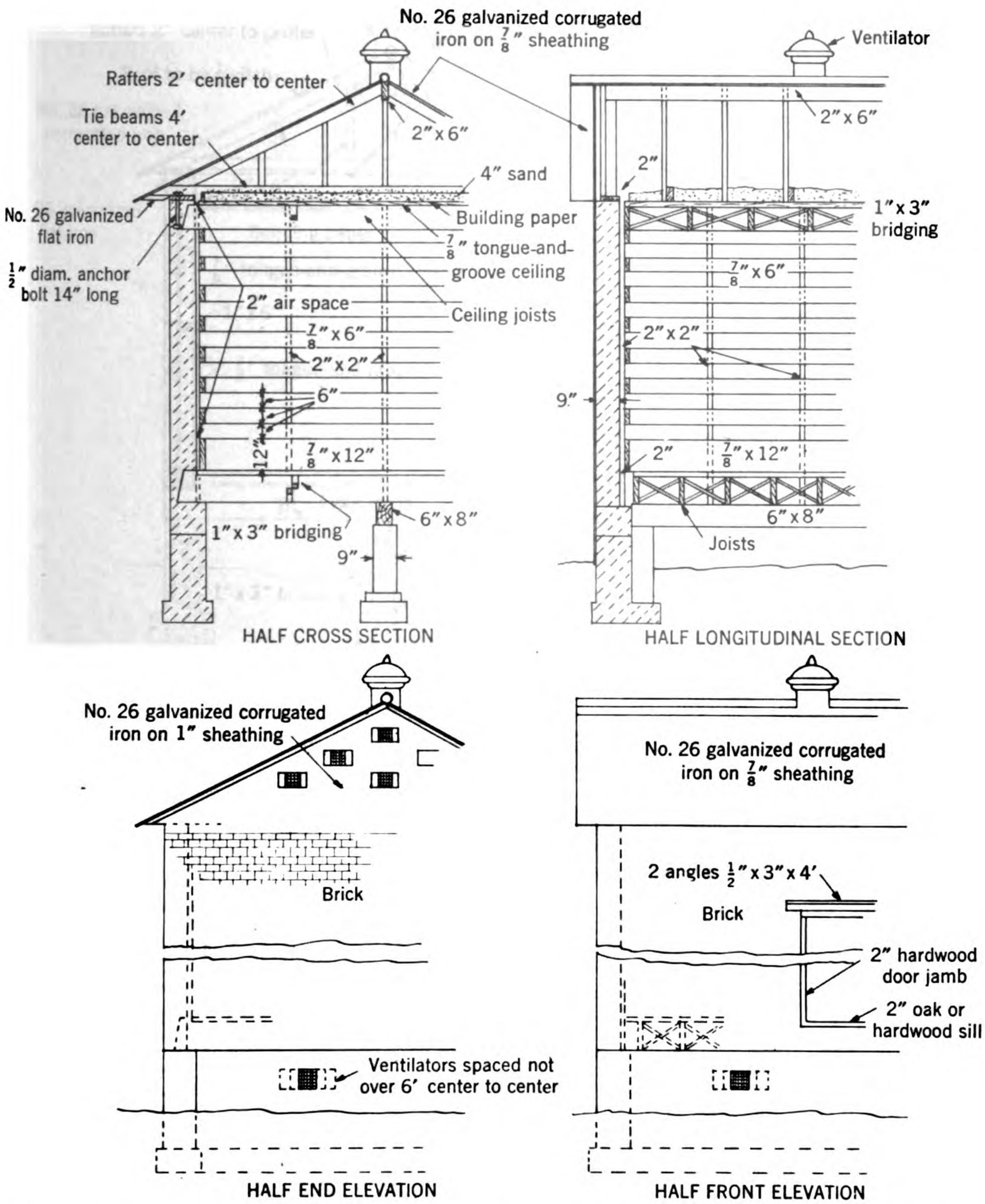

No. 26 galvanized corrugated iron on 7/8" sheathing
Rafters 2' center to center
Tie beams 4' center to center
2"x 6"
4" sand
No. 26 galvanized flat iron
Building paper
7/8" tongue-and-groove ceiling
1/2" diam. anchor bolt 14" long
2" air space
Ceiling joists
7/8"x 6"
2"x 2"
6"
12"
7/8"x 12"
1"x 3" bridging
6"x 8"
9"
HALF CROSS SECTION
Ventilator
2"x 6"
2"
1"x 3" bridging
7/8"x 6"
2"x 2"
9"
2"
7/8"x 12"
6"x 8"
Joists
HALF LONGITUDINAL SECTION
No. 26 galvanized corrugated iron on 1" sheathing
Brick
Ventilators spaced not over 6' center to center
HALF END ELEVATION
No. 26 galvanized corrugated iron on 7/8" sheathing
2 angles 1/2"x 3"x 4'
Brick
2" hardwood door jamb
2" oak or hardwood sill
HALF FRONT ELEVATION

FIGURE 10.- Standard brick magazine (as recommended by The Institute of Makers of Explosives). Specifications: Brick to be medium-soft and laid in cement mortar containing not over 25 percent lime. No metal to come in contact with explosives packages. Floors to be blind-nailed; lining nails to be countersunk. Floors and ceiling to stop at 2- by 2-inch lining supports, leaving 2-inch ventilation spaces around the walls. Lattice lining, as shown, with 12-inch base boards and 6-inch wall boards spaced 6 inches apart. Gable or hip roof. Bullet-proof sand roof, as shown. Box formed by laying floor of tongue-and-groove bóards on ceiling joists and building 1- by 4-inch rim line with one layer of building paper and filling with not less than 4 inches of coarse, dry sand. If bullet-proofing of roof is not necessary, a ceiling should be built of 7/8-inch tongue-and-groove boards or wall boards to stabilize temperature within the magazine.

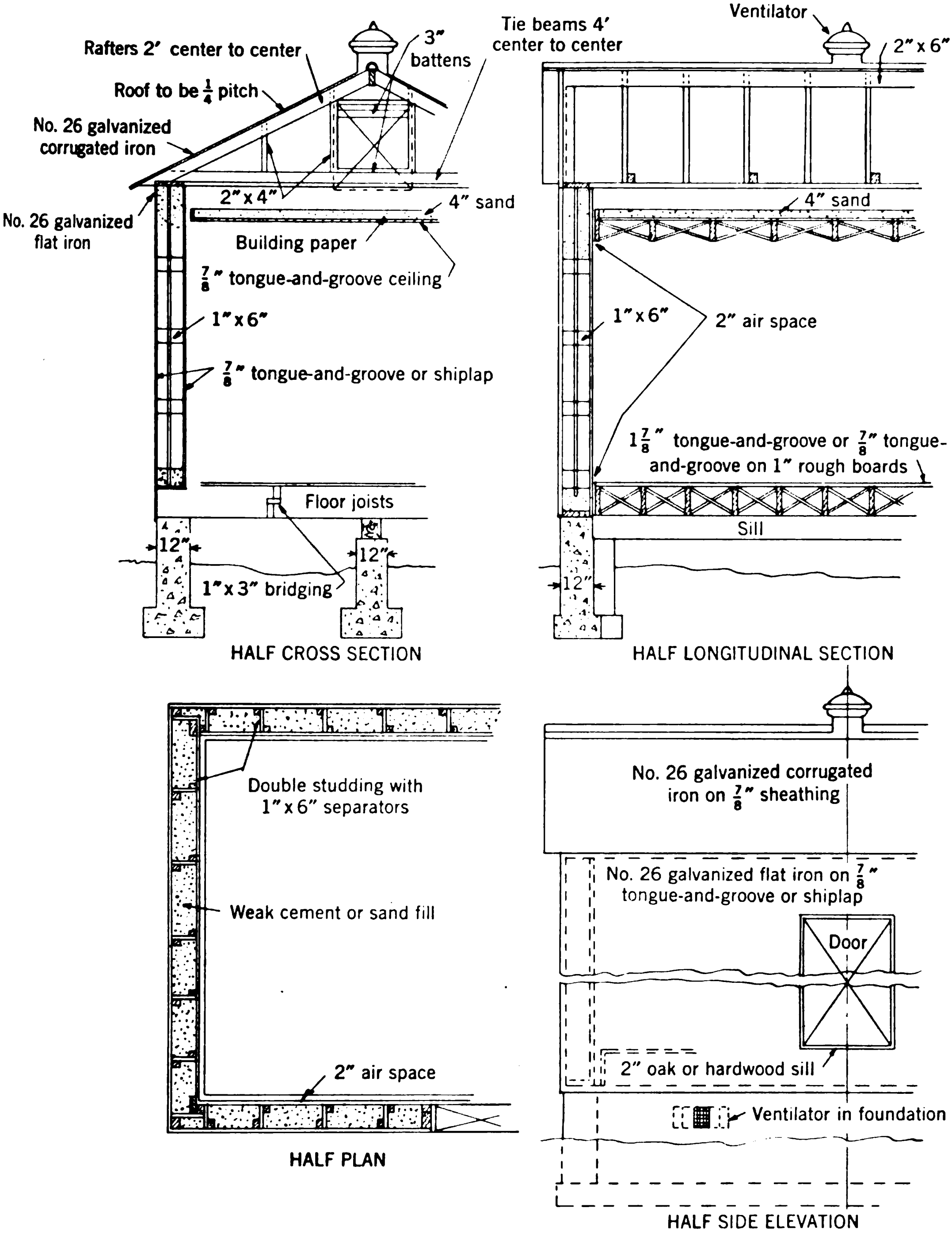

Rafters 2′ center to center
Roof to be $\frac{1}{4}$ pitch
No. 26 galvanized corrugated iron
No. 26 galvanized flat iron
3″ battens
Tie beams 4′ center to center
2″ x 4″
4″ sand
Building paper
$\frac{7}{8}$″ tongue-and-groove ceiling
1″ x 6″
$\frac{7}{8}$″ tongue-and-groove or shiplap
Floor joists
12″
12″
1″ x 3″ bridging
HALF CROSS SECTION
Ventilator
2″ x 6″
4″ sand
1″ x 6″
2″ air space
$1\frac{7}{8}$″ tongue-and-groove or $\frac{7}{8}$″ tongue-and-groove on 1″ rough boards
Sill
12″
HALF LONGITUDINAL SECTION
Double studding with 1″ x 6″ separators
Weak cement or sand fill
2″ air space
HALF PLAN
No. 26 galvanized corrugated iron on $\frac{7}{8}$″ sheathing
No. 26 galvanized flat iron on $\frac{7}{8}$″ tongue-and-groove or shiplap
Door
2″ oak or hardwood sill
Ventilator in foundation
HALF SIDE ELEVATION

FIGURE 11.- Standard sand-filled or weak concrete-filled magazine (as recommended by The Institute of Makers of Explosives). Specifications: Outside and inside sheathing to be tongue-and-groove boards to prevent loss of sand. Space between outside and inside sheathing to be filled with weak concrete mortar of approximately 1 part Portland cement and 7 to 10 parts of sand or 6 to 12 inches of weak mortar over the sills and coarse, dry sand in the remaining space. Bullet-proof sand roof, as shown. Floor and ceiling to stop 2 inches from walls to provide ventilation. Nails in walls and floors to be concealed.

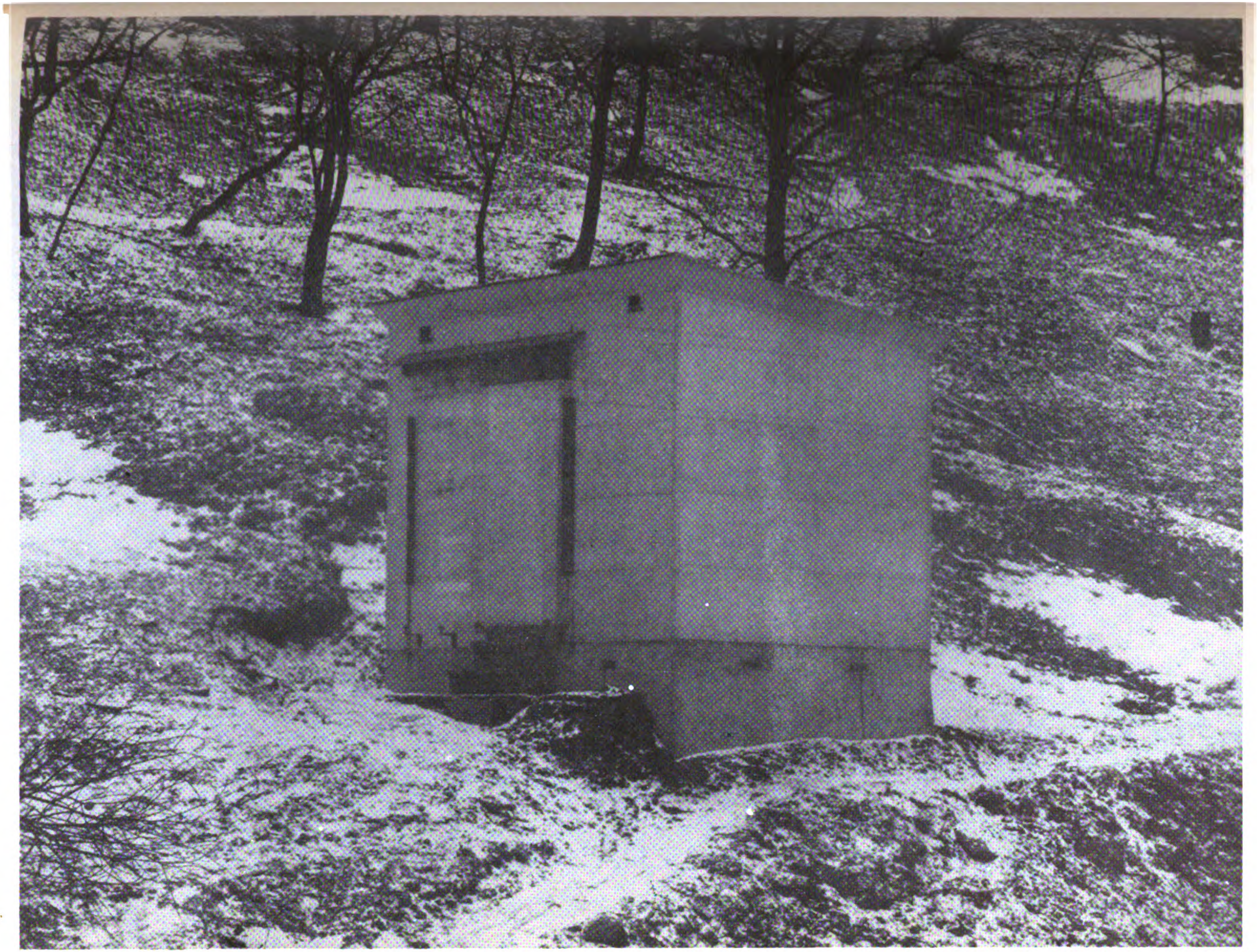


FIGURE 12.- Bureau of Mines cement-mortar magazine.

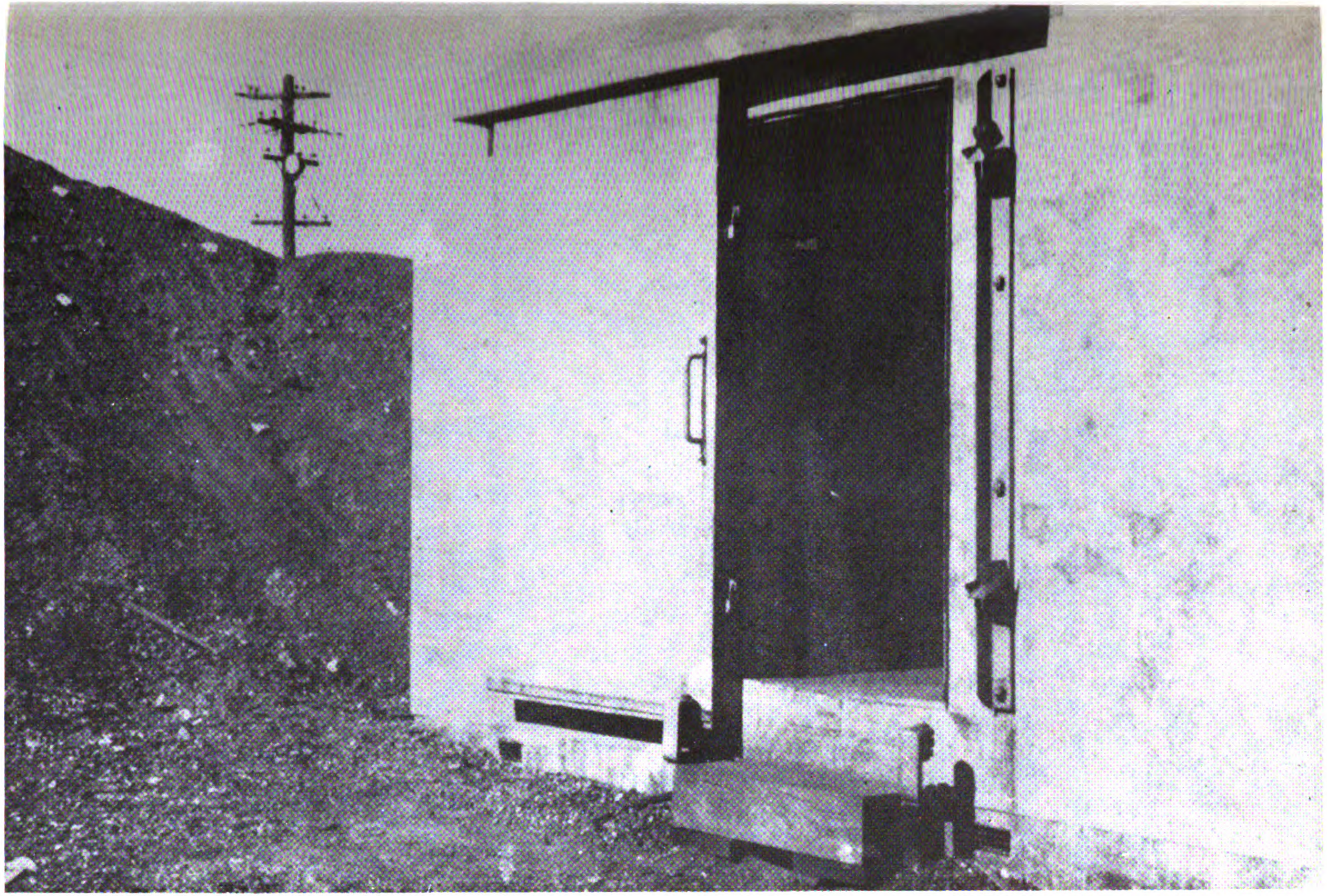


FIGURE 13.- Concrete-filled sliding door similar to door used on Bureau of Mines magazine.

Lighting in the magazine should be natural or by permissible lights; if a magazine is electrically lighted, the lamps should be of the vapor-proof type, the switch should be outside the building, and the wiring should be in conduit.

Smoking, open lights, and open flames should not be allowed in or near a magazine.

Only tools made of wood or other nonmetallic material should be used in opening containers of explosives.

Floors of magazines should be kept clean. Empty boxes, paper, and trash should not be allowed to accumulate; such material should be destroyed by burning at a safe distance from the magazine.

Explosives should be so stored that the oldest stock is used first.

Cases of explosives should be stored top-side up; in other words, so that cartridges are lying flat. However, they should be turned at regular intervals as this will help to prevent their deterioration.

Preferably, cases of explosives should not be piled in stacks more than [illegible] feet high.

Cases containing explosives should always be lifted and set down carefully, never slid over one another or dropped from one level to another or otherwise mishandled.

The area surrounding the magazine should be kept free of dry grass and brush or other combustible material for at least 25 feet, preferably 50 feet, in all directions; if feasible, this area should be covered with cinders or other material to prevent the growth of grass, brush, and weeds.

Only authorized persons should be allowed in the magazine. One person should be made responsible for the operation and be held accountable for the contents of the magazine.

CONCLUSIONS

Federal explosives investigators engaged in the administration of the wartime Federal Explosives Act inspected many thousand storages of explosives and found not more than 10 percent of them to be safe or efficient. In thousands of instances, the method of storage was so defective as to border on criminal carelessness. High explosives in considerable quantities were "stored" under or on rock ledges or even loose rocks in quarries or along hillsides or road cuts, on the counter in company stores in coal-mining communities, in coal sheds or chicken houses in small towns, in barns, milk houses, tool sheds, or even in the kitchen pantry on farms, behind the bar in saloons, and under the kitchen stove in some mining communities. In at least half of the relatively small storages (50 pounds or less) no attempt was made to protect the explosives against theft by storing them under lock and key.

In scores of so-called explosives magazines that had some semblance of protection against theft, the protection usually was merely a hasp and stapl and a cheap lock that could be forced in a few minutes with an ordinary hammer, bar, or chisel. In many instances, if the lock should hold, entrance could be had by forcing a door panel or breaking a few panes of glass in a window, or some boards or corrugated sheet iron could be removed with a crow bar. In fact, in virtually every State in the Union essentially no protection was provided against theft of stored explosives, and mischievous boys (and sometimes girls) were almost invited to break into the so-called explosives magazines.

As a result of this almost criminal carelessness, hundreds of small children every year come into possession of explosives (dynamite, black blasting powder, detonators), with the result that every year scores of the lose fingers, arms, feet, or eyes.

Through the administration of the Federal Explosives Act, explosives storage has been improved greatly throughout the United States, and it is hoped that the good work that has been accomplished and the benefits that have been realized will not be lost with the advent of peace and the consequent recessing of the act.

The thousands of storages of explosives of all sizes that have underg improvement, in many instances through construction of new magazines in sui able places, have far more than justified the expenditure of effort and fu involved in the administration of the Federal Explosives Act since it went into effect upon its passage on December 26, 1941.